Zenneck Memorial Lecture

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We are assembled here this evening to commemorate one of the pioneers in radio science, Prof. Jonathan Adolf Wilhelm Zenneck. The occasion and the location of this meeting could not have been chosen more appropriately. This is the first General Assembly of URSI to be held in Zenneck's native country, Germany. Zenneck was a great advocate of URSI. Before World War II, he was chairman of the German National Committee and vice president of URSI, two posts which are now held by one of his former students, Professor Diéminger. After the War, Zenneck was elected honorary president of the German National Committee.

Munich is the town where Zenneck finally settled in 1913, after having occupied professorships at several other universities, and having spent two years in industry as the head of a research laboratory. No offer, no matter how attractive, persuaded him to again leave this town with its beautiful surroundings, and this university which provided him with a new physics laboratory, and this auditorium which was designed by Zenneck, in close cooperation with the architect, to meet the requirements for his famous lectures in experimental physics which had a student audience of up to eight hundred.

During the General Assembly of URSI in Tokyo (1963), Sir Edward Appleton had consented to deliver today's memorial lecture, but unfortunately he died shortly afterwards. In him, another pioneer in radio science passed away, and URSI lost another of its most distinguished and merited members.

When Professor Dieminger asked me whether I would be willing to take the chair today, I hesitated for a moment because I felt that a more prominent personality should substitute for Sir Edward. However, when I searched my memory for associates of Zenneck who knew him well enough to appreciate both his human and his scientific qualities, I realized that their ranks have diminished considerably in recent years. I also realized that there were only a few who were as closely associated with him for as many years as I, and whose scientific career had been so profoundly influenced by him. I, therefore, considered it not only an honor, but also an obligation of gratitude to Zenneck when I accepted Professor Dieminger's invitation.

Addressing you in these, to me, so familiar surroundings, recalls nostalgic memories. Munich is the town where I was born and raised. The Technische Hochschule is my alma mater. In this room I had my first lecturing experience, when Zenneck was out of town and had asked me to be his stand-in. The years that I spent downstairs in the physics laboratory, then called the Zenneck Institute, as a student, as an assistant, and later as a lecturer, were the most rewarding and enjoyable years of my life. Of course, at that time, I did not have the slightest inkling that one day I would have to cross an ocean to visit this familiar place again. But life is unpredictable. It does not always require major events, like a war, to change one's destiny as it did in my case. Sometimes, seemingly unimportant or accidental events may bring about a drastic change.

This was the case in Zenneck's life, a man whose professional career began in zoology, and rather abruptly and unexpectedly turned to physics. Zenneck received his doctor's degree in zoology, and afterward he continued in this discipline with research studies at the National History Museum in London. Having returned to Germany to fulfill his military duty, he received two letters while he was still in the service—both offering him an assistantship. One was from Professor Braun, his former physics teacher, and the other was from the renowned zoologist Professor Eimer, his "doctor-father." The reason Zenneck became a physicist was because of a time lag of two weeks between these two letters. Professor Braun's letter arrived first and Zenneck accepted because he wanted to spend more time at a university—and he liked physics. But he still intended to return to zoology. Therefore, when Eimer's letter arrived he asked Braun to release him, so that he could stay in zoology. But Braun wrote back that since he now had him as an assistant, Eimer should look around for someone else. At this time, assistantships were not very attractive, since the salary was less than thirty dollars a month.

I do not know whether Zenneck ever regretted becoming a physicist, but I am sure he would have achieved the same fame as a zoologist had the two letters reached him in the reversed sequence. As a matter of fact, many years later when Zenneck was already a renowned physicist, Mrs. Zenneck was asked by her neighbor, at a university dinner, who happened to be a zoologist, "Zenneck? There was once a zoologist by that name who did very good work—this man has been a disappointment because one does not hear of him anymore!"

Before I recall Zenneck's achievements as a physicist, I would like to give a synopsis of his life history which is, indeed, quite unique. Zenneck began writing his own memoirs, but unfortunately he never completed them. They end, with the exception of a few notes, with the year 1919—the year of his return from an internment camp in the United States, after World War I. His memoirs are very interesting and also humorous to read. They reflect his inborn humor, which broke through in all his speeches and lectures, a humor which is characteristic of the natives of that part of Germany from which he came.

Jonathan, or Jo as he was called in his youth, was born on April 15, 1871, in Ruppertshofen, Württemberg, a village some 150 km west of Munich. His ancestry can be traced to the year 1397, some 220 years before the English pilgrims who sailed on the Mayflower set foot on the American continent. Zenneck's forefathers, for six successive generations, were Protestant ministers. As the oldest child of a pastor's family of six children, he did not grow up in affluence. The modesty which surrounded him in his childhood became a characteristic of his personality. Still, he knew no want during his childhood, and he remembered both his parents with great affection and admiration. Growing up in the country kept him close to nature, and this attachment lasted throughout his entire life. There were always a number of pets around the house, of which he was very fond, and which may have stimulated his interest in zoology. In later years, he talked frequently about their "menagerie" at home which comprised—though not all at once—one poodle, two jackdaws, one raven, one parrot, two squirrels, one fox, eight deer, and even two monkeys.

The rustic humor of the natives is exemplified in his memoirs by a little story about their family doctor. One night when little Jo was sick, his mother sent for the doctor, who lived a few walking hours away. After the doctor had examined him and diagnosed his sickness as an ordinary gastric disorder, he did not conceal his annoyance about his disturbed night's rest. Jo's mother said,

[1] Presented at the 1966 General Assembly of URSI in Munich.

"But, Doctor, every time I look at him he has cramps!" The doctor replied, "If you looked at me all day, I would get cramps too!"

Zenneck's formal education began in 1877 with a two-year attendance at the village school followed by ten years of "gymnasium," which is a secondary school with classical bias. The upper four grades he spent in theological seminars, which were accessible also to students with other professional interests. These state-supported seminars provided free room and board and even some pocket money for the students. It was never Jonathan's intention to follow in the footsteps of his forefathers. His professional goal at that time, and even in later years when he entered the university, was to become a naval officer, in spite of the fact that he was a "landlubber" who had never seen the ocean.

While he was living with his parents, he had an unusual opportunity to widen his horizon and to learn about people and customs of other countries. His parents used to board foreign students who lived as members of the family. They came from well-to-do families who sent their youngsters to Germany to learn the native language of the famed poet Friedrich von Schiller. Lasting friendships developed between some of them and Jonathan. One of these students later became the president of the National Physical Laboratory in Teddington, near London—Sir Joseph Petaval. Another one was the subsequent French General Raoul, who had lived with the Zenneck family for a period of six years.

In 1889, Zenneck entered the famous "Tübinger Stift," a theological institution with the same privileges for the students as the aforementioned theological seminars, and studied at the University of Tübingen, mathematics and natural sciences. During the first three semesters, philosophy was a mandatory subject with which Zenneck was not at all impressed. Even in his later years, he did not think very highly of philosophy. In his memoirs, he quotes the physicist Lichtenberg, who became more famous for his aphorisms than for his "Lichtenberg figures" in corona discharge. Lichtenberg defines philosophy as "the misuse of a terminology expressly invented for that purpose."

The Chair of Experimental Physics in Tübingen was occupied at that time by Professor Braun, the inventor of the cathode ray tube, formerly called Braun's tube. Braun, who later received the Nobel Prize together with Marconi, stimulated Zenneck's interest in physics, and eventually caused his defection from zoology. But at that time Zenneck's heart was still set on zoology, which was taught by Professor Eimer. It was in Eimer's laboratory that Zenneck spent most of his time, and where he worked for his doctor's degree—the subject of which was "the predisposition of the coloring and its physiological causes in the embryos of ring snakes."

In the spring of 1894, Zenneck passed the state examination for secondary school teacher in the state of Württemberg and shortly afterwards, his doctor's examination, with zoology as the principal subject, and mathematics and physics as subsidiary subjects. Subsequently, he received a state scholarship which enabled him to continue his research at the Natural History Museum in London. With great fervor and diligence, he worked on a zoological book which he completed a few years later, because in the fall of that same year he had to return to Germany for military service. Before his service was over, he received the eventful letter from Braun, who, in the meantime, had accepted the chair for experimental physics at the University of Strassbourg. Thus the year 1895, when he was 24 years old, marks the beginning of Zenneck's career as a physicist. While he held the assistantship, he taught mathematics, botany, and zoology at a secondary school. In spite of this teaching burden, he still found time to do research, but it was now in physics.

The major contributions Professor Braun had made at that time were the aforementioned cathode ray tube and the tuned radio transmitter called "Braun's transmitter." (Marconi's original transmitter was untuned.) Prior to Braun, the opinion prevailed that the wavelength in Marconi's transmitter was very short, and essentially determined by the size of the spheres of the spark gap, as in the case of the Righi oscillator, and the main purpose of the antenna was to guide the waves up to a greater height, thus increasing the range of line-of-sight. Braun intentionally wanted to use longer wavelengths, which he produced with an LC circuit to which the antenna was coupled. Although the true functioning of the antenna was still not quite clear—Braun's antenna, by the way, was not grounded—this transmitter showed very promising results. A company was formed to explore its practical usefulness, and to compare its performance with that of the Marconi transmitter. In the fall of 1899, Zenneck was put in charge of the experiments which were conducted near the coastal city of Cuxhaven, on the North Sea. The experiments were so successful that by the end of the same year, Zenneck was given the task to establish radio communication links between the lightships, located in the mouth of the river Elbe, and a station on the Island of Neuwerk. The completion of this task marked a historical event in the history of radio science. This was the first application of wireless communication to navigation. In 1956, the city of Cuxhaven unveiled a monument in memory of Zenneck's pioneering contribution to navigation at the dawn of this century.

The two years which Zenneck spent in Cuxhaven, and on the North Sea, were not only filled with hard work, but also sprinkled with adventures. For instance, during his first experiments, the transmitter was stationed in the drawing room of an excursion ship. The induction coils were immersed in mineral oil. During heavy seas, parts of the coils were uncovered, and sparks between the coils ignited the oil, causing a flame that reached up to the ceiling of the room. By some stroke of luck, when the ship moved in the opposite direction, the oil flowed back and extinguished the flame. The owners of the ship did not like this, and refused to have such dangerous experiments performed any longer on board their ship. Later, when a heavier oil was used, and Zenneck demonstrated that this oil could not be ignited by sparks, the owners permitted the continuation of the experiments. But, the heavy oil also followed the laws of inertia and gravity, and during very heavy seas some oil spilled on the linoleum floor of the drawing room, where it acted as a perfect lubricant. This caused the storage batteries to slide back and forth and bounce against the wood panelling. Zenneck fell down, trying to prevent any damage, and soon a sailor, who mumbled something about "landlubber," joined him in his involuntary floor gymnastics.

Since the available transportation to the lightships was inconvenient and very slow—sometimes it took two to three days to reach one of these ships—Zenneck decided on a private conveyance. He bought an old sailboat and converted it into a seaworthy vessel, but only after it turned over on its first voyage out. Still, in bad weather, sailing in a small boat on the North Sea is quite dangerous. Without his sportsmanship, personal courage, and his eagerness to combine research with practical application, he would not have been able to accomplish his task within a period of not much more than a year. Of course, there was little time left for basic research, but numerous problems which he encountered during this period gave him enough material for research in the years to come.

In 1901, Zenneck returned to Strassbourg. By then, he had decided on an academic career in physics. In that same year he submitted his inaugural dissertation, which is required to become a lecturer.

Now there follows an outwardly quiet period of four years, in which he developed an explosive scientific activity. He not only published nineteen papers, but also a book of more than a thousand pages entitled "Electromagnetic Oscillations and Wireless Telegraphy." The second part, on wireless telegraphy, he later expanded and published under the title "Textbook of Wireless Telegraphy." It was jokingly called "The Bible of Wireless Telegraphy." His books found international acclaim, and have been translated into French and English.

Zenneck's first appointment to a professorship was at the Technical University of Danzig in 1905. One year later, he followed a call to the Technical University in Braunschweig to take the Chair of Experimental Physics. His stay in Braunschweig had lasting consequences. He fell in love with a member of the skiing party which he and his assistant had organized for the winter months. The young lady, Miss Olga Haeseler, the daughter of one of his colleagues, soon became Mrs. Zenneck. But, before his marriage, he accepted an offer by a large chemical corporation, the Badische Annilin and Soda Fabrik, to establish and direct a new physics laboratory. At that time, a physics laboratory in a chemical firm was heretical and something unheard of. However, the firm was developing electric arc furnaces for the synthesis of nitric oxide, which had been invented by the Norwegian physicist Birkeland. These furnaces created problems that were beyond the realm of

chemists and electrical engineers, and required a physicist. When the company, together with the Norwegian company, Norsk Hydro, constructed production plants in Norway, Zenneck and his wife moved there and stayed for more than a year.

Although Zenneck liked his job in industry, he still preferred an academic career, and when he received another call to the Technical University of Danzig to succeed Max Wien, he accepted. Max Wien invented a quenched spark gap that was still in use for emergency transmitters on lifeboats long after tube transmitters had been introduced for communication. Zenneck's position was director of the Physics Laboratory, which since his first professorship, had been furnished with the most modern instruments. He intended to stay in Danzig for a longer period of time and refused a call to the Physikalisch Technische Reichsanstalt, but after two years, when he received a call from the Technical University, Munich, he could not resist. So, in October of 1913, he moved to Munich. During the months when the laboratory was being reorganized, he comforted his assistants by saying, "Within two semesters, everything will be ready and we can begin our scientific activity." But, in the meantime, World War I began and Zenneck was called to active duty as captain in the reserve.

In December of 1914 he was recalled from the front lines, and sent on a mission to the United States, together with Professor Braun. Their assignment was to be expert witnesses for the German-owned transatlantic radio station in Sayville, Long Island. The station had become involved in a patent litigation, the aim of which was to force the station off the air. It was the only communication link between Germany and the United States, after the transatlantic cables were cut. The journey to America through the British blockade was another adventure in Zenneck's life. The mission was successful, as the plaintiff requested indefinite postponement of the trial.

Later, Zenneck was engaged by several United States companies as an expert witness in other patent litigations. When the United States entered the War, Zenneck had to endure a period with quite unpleasant memories. But, several months later we find him, rather content, in an internment camp in Georgia, where he shared his fate with men from all walks of life, among whom was the famous conductor of the Wagner Festivals in Beireuth, Dr. Carl Muck. Zenneck passed his time with raising vegetables, giving lectures, and doing scientific work. He even had a scholar who was working on a doctoral dissertation. Zenneck was released in 1919, and returned to Munich. Braun, who had lived undisturbed in Brooklyn, did not return. He died in 1918.

Here Zenneck's memoirs end. Much had changed in Germany while he was away. The after-effects of the lost war, revolution, and inflation, marred the working conditions which he had hoped to find when he accepted the professorship in Munich. The number of students had increased to such an extent that the facilities, particularly the lecture room, were entirely inadequate. He continued to receive calls to other universities, and being very discouraged, he was almost ready to leave. But then he was promised a new laboratory and a new lecture room. However, because of the inflation, it was not until 1926 that the construction of this wing was completed.

In the meantime, Zenneck had been elected rector, an office which he held from 1925 to 1927. In 1926 he became a member of the presidium of the Deutsches Museum. When Oscar von Miller, the creator of this museum retired in 1933, Zenneck became Chairman of the Presidium. Zenneck also held other honorary offices, honorary from the financial point of view, but quite demanding with regard to work. Simultaneously, of course, he had to fulfill his teaching obligations, and the quite demanding job of Director of the Physics Laboratory, which had about thirty students working on their masters or doctors theses. Therefore, after his return to Munich, he never found time for his own laboratory work, which he had always enjoyed before.

When he retired from the university in 1939, he was fully occupied with the Deutsches Museum, and the Zentralstelle fuer Ionosphaerenforschung (Center for Ionospheric Research) which he had founded in 1939 and directed until it was dissolved after World War II. The years after the war until 1953, when he retired from the presidium of the Deutsches Museum, were filled with the almost hopeless task of reconstructing the Museum, which had been heavily bombed in 1944.

Zenneck never really retired. When I visited him for the last time in 1957, he was 86 years old—his table was still piled up with work!

Zenneck's contributions to the physical sciences are spread over many areas. His first papers, published in 1898 and 1899, pertained to Cladny's sound figures and the oscillation of circular plates. His interest in acoustics continued through his professional life, and quite a few papers on acoustical subjects were published by him and his doctoral candidates. One, which he published in 1903, was a regress to zoology. It concerned the question of whether fishes have perceptivity for sound. He was the first to prove beyond any doubt that this is indeed the case. In later years, Zenneck became interested in the importance of the pulling effect of wind instruments in orchestras. The pulling effect occurs when acoustical, or electrical oscillators, with about equal or harmonically related frequencies are coupled. Without coupling, two oscillators, like organ pipes, produce a beat note because there is always a slight deviation in frequencies. But, if they are coupled, the beat note disappears, indicating that the frequencies are now alike, or in an exact harmonic relationship. I remember an experiment for which two trombone players of the State Opera were hired. When the two were in the same room, they played the same note without beat, but when they were in separate rooms, interconnected by microphones and earphones so that they could hear each other, they were unable to hit the same note exactly.

Another subject of Zenneck's interest was room acoustics, in particular the development of methods for improving the acoustics of large auditoriums. The Prinzregenten Theater in Munich is one example where the acoustics had been greatly improved as a result of these investigations.

Of particular importance were Zenneck's contributions to radio communication in its pre-World War I period. Many of his contributions have been forgotten because they pertained to spark transmitters which are no longer in use. There are other contributions which may appear trivial today, but if they are projected back to the turn of the century, they are not trivial at all. In connection with his experiments with the Braun transmitter in 1899, Zenneck invented the resonance wave meter, using a fixed capacity and a variable inductance (exhibited in the Deutsches Museum). The first tuned receiving antenna also goes back to that time and preceded the publications by Lodge and Marconi. The use of a tuned reflector wire for the transmission in one direction also originated with Zenneck. He calculated the first tables of the resistivity of wires at high frequencies. To obtain these data, he had first to evaluate the corresponding Bessel functions with complex argument (nowadays called Ber-and-Bei functions) which were not tabulated at that time. His results were quoted for many years in the widely used "Tables of Functions" by Jahnke-Emde. Nowadays, of course, we would use a computer, but the only computer then was the slide rule.

In the early days of spark transmitters, only a few people realized that the spark was a necessary evil—but more an evil than necessary. Those who did sought for methods of producing high frequencies without sparks. In 1899, Zenneck published the first paper on frequency multiplication with iron cores. Many papers on this subject followed in the years to come. Zenneck's pioneering work in this area has been recognized in an article by Mumford, "Some Notes on the History of Parametric Transducers," published in 1960 in the IRE.

In Zenneck's experiments with high frequencies, Braun's cathode ray tube was a most important tool. He became a great advocate of the tube, which he used to call his "favorite apparatus." He published a number of papers concerning applications and improvements. It is interesting to note that until December, 1921, this means within a period of 23 years after the invention of the cathode ray tube, there were only 89 publications, or about 4 per year, in which the use of the tube was reported. This survey was conducted in 1923 by the National Bureau of Standards in Washington. Today, there is a cathode ray tube in almost every family—in the form of a TV picture tube.

The name Zenneck is most frequently quoted in the literature in connection with the Zenneck-wave. This is a surface wave which is guided by the interface between a conducting and a nonconducting medium. The history of this wave goes back to Zenneck's first experiments in 1899, where he observed that the electric field of a

transmitter has a forwardly directed component which depends on the ground condition. This was contrary to the opinion prevailing at that time, that the waves radiated from the antenna propagate on a straight path like light. In order to explain his observations on the basis of Maxwell's theory, he considered a simplified model, namely a plane interface between a homogeneous earth and the air, and he assumed a plane wave. The solution of the boundary value problem led to a wave whose field decays exponentially in both directions perpendicular to the interface. In other words, the energy remains confined to the proximity of the interface. The solution explained the observed phenomena that the electric properties of the ground play an important role in the propagation of radio waves along the earth. This, essentially, was all Zenneck intended to show. His solution was later termed "Zenneck-wave." In 1909, Sommerfeld formulated the problem of wave propagation along the earth more rigorously by assuming instead of a plane wave, a field which is excited by a vertical dipole. He divided his solutions into two parts, a surface wave describing a radially propagating Zenneck-wave, and a space wave containing that portion of the field which is radiated into space. When Weyl, in 1919, treated Sommerfeld's problem in a somewhat different manner, he came to the conclusion that the Zenneck-wave does not exist. This started a controversy about the Zenneck-wave which lasted 30 years. I do not wish to go into the details of this matter, because I might stir up this controversy again. Zenneck never participated in these discussions. He was aware that his solution could not *quantitatively* describe wave propagation along the earth. However, the Zenneck-wave was instrumental in the development of the concept of surface waves, the kind now called (in the U.S.A.) "trapped" surface waves. The physical reality of such waves was denied by many theorists until trapped surface waves were demonstrated experimentally.

In the late twenties, Zenneck became interested in the ionosphere. This was soon after Appleton had made his first historic ionospheric measurements, using a frequency sweep method and Breit and Tube had published their famous echo method. In 1928, when I was in line for a master's thesis, Zenneck gave me the task to develop equipment for echo measurements on the ionosphere, which could be used with the Munich broadcast transmitter. He told me that he had already ordered a loop oscillograph for recording the echoes, and in the meantime I should use a string oscillograph, which was available, though not good enough for the actual measurements. Since I had heard so much about Braun's cathode ray tube, I decided to use one for investigating various methods for producing short pulses. I liked working with this tube so much that I continued using it until the entire bench set-up of an ionospheric sounding equipment was completed. The use of a cathode ray tube, in place of a loop oscillograph, required synchronization between the time deflection on the cathode ray tube and the pulse repetition rate of the transmitter. (Transmitter and receiver were separated at that time because it was not yet known that reflection occurs also for vertical incidence of the waves.) This synchronization was achieved by pulling the oscillator for the time deflection with the received pulse train. When I demonstrated the set-up to Zenneck, he appeared to be very pleased and suggested that I should use this method for the actual measurements.

Thus, the Zenneck Institute became the first to apply the cathode ray tube to ionospheric soundings. I must admit that working with these old-fashioned cathode ray tubes, which had a cold cathode and were operated with an electrostatic machine, was not all pleasure. Sometimes it required all sorts of tricks to maintain a stable gas discharge in the tube. But, the advantages of using a cathode ray tube for ionospheric soundings were so obvious that it soon became general practice.

The second student to join Zenneck's ionospheric venture was Professor Dieminger, who later specialized in this field and who is now the Director of the Institute for Ionospheric Physics of the Max Planck-Institute. At that time, Zenneck already had a transmitting station available in the Alps, which later developed into the Ionospheric Research Station (Herzogstand/Kochel). This station was in operation until after World War II, when it was dismantled and the equipment shipped to the Bureau of Standards where it was put to eternal rest. Many contributions to the exploration of the ionosphere by Zenneck and his students, originated at this station. Several of his former students are still very active in this field.

An important contribution to radio science was Zenneck's Journal, Zeitschrift fuer Hochfrequenz Technik und Elektroakustik. As editor, he personally reviewed each paper that was submitted for publication, and he rarely asked anyone else for an additional review. Furthermore, for every issue he wrote comprehensive summaries of foreign publications which he felt would be of interest to the readers of his Journal.

It would take too long to enumerate all Zenneck's contributions in other areas of physics and applied physics. Professor Dieminger has written an excellent monograph about Zenneck, which is published by the Deutsches Museum. This monograph contains a rather complete list of Zenneck's publications. Not all of the 190 papers listed are on scientific subjects. Some are obituaries, others are articles commemorating anniversaries of famous personalities. Discounting these, there still remains the respectable number of some 150 scientific publications.

As an academic teacher, Zenneck fulfilled his obligations with the same devotion, effectiveness, and enthusiasm with which he conducted research.

Zenneck's lectures in experimental physics were famous, and I am sure that none of the thousands of students who attended his lectures will ever forget them. Zenneck was aware that most students considered physics more or less a necessary evil. Therefore, he endeavored to present the subject in a most attractive and impressive manner. Every experiment was carefully designed to first demonstrate most clearly the physical phenomenon, and second to leave a lasting impression, so that a student who was not quite attentive during the lecture would at least remember the experiment. It was not simple to set up the experiments in such a manner that they could be clearly seen from every place in the room. In some cases, this was simply impossible—as in optical diffraction. Therefore, when I saw the first gas laser I thought of Zenneck and how happy he would have been if he could have had a laser for his lectures. In order to keep the students' attention (during the carnival season it was sometimes difficult to even keep the students awake) he injected little jokes, or told some episodes of his life which were related to the subject matter. One of his graduate students once composed a little poem about the life in Zenneck's Institute. I will quote the portion which pertains to Zenneck's lectures because it characterizes them so well, in a few lines. I cannot translate it into English because it would lose its impact, but I think most of you will understand the German text.

"Schüsse krachen, Lichter Blitzen, Funken entladen sich aus Spitzen, Motore surren, Dampf bricht aus, von Beifallsgetrampel dröhnt das Haus. Witze noch steigern die Begeisterung: Kurz, das physikalische Theater ist in Schwung . . ."

Zenneck was opposed to what he called "chalk physics" (this, of course, referred only to lectures in experimental physics). Still, he could not avoid writing down some relations and formulas and making sketches to explain the experiments. But an ordinary blackboard would not have been of much use to those who were sitting far back in this room. To overcome this problem, Zenneck invented a "writing projector." It is now standard equipment in lecture rooms and is called a "viewgraph."

In spite of his workload, Zenneck made regular rounds through the beginners' laboratory and spoke with each student. On the other hand, he very rarely visited the graduate or post graduate students. He felt that the advanced students should learn to work independently without someone looking over their shoulders. Of course, he was available in his office if these students wanted to discuss their problems with him.

To his assistants, Zenneck was a most considerate and pleasant boss. He let them live their own lives, without interference from him. Of course, each one had his duties, but there was plenty of time left for research. He did not mind if his assistants arrived at noon, while he himself had already done a half day's work. He remembered the time when he was assistant to Professor Braun. When Braun wanted something in the early morning hours, he would go to his assistants (who were housed in the laboratory building) and sit at their bedside, discussing the problem with them. The informal and congenial atmosphere which prevailed in Zenneck's Institute made it exceedingly pleasant to work there.

It is hard to believe that a man like Zenneck, who had such a passion for work, could still find time for hobbies. Indeed, he had quite a few hobbies! Most of them were of the sporting kind, ex-

cept in his younger years he played musical instruments, particularly the piano, and during his entire life he liked to paint landscapes. In the summer he liked to hike, and during the winter he enjoyed skiing. He was one of the first to take up skiing when it was introduced into Germany at the turn of the century. While in Munich for many years he rented a chalet in the Alps, and this chalet served not only as a skiing refuge for Zenneck and his family, but also for his assistants and graduate students. Sommerfeld was a frequent member of these skiing parties.

Another of Zenneck's activities was sailing, a sport he indulged in particularly while he was at Cuxhaven, in Danzig, and in Norway. As sailing was, to him, not only a pleasure but also a means of transportation, so was bicycle riding, which was his principal means of transportation on land. Zenneck never owned an automobile, although he had a driver's license. While his assistants and students arrived at the University by car or motorcycle, Zenneck came by bicycle.

Another favorite was horseback riding. For years, Zenneck had his own horse, and early every morning he rode in the English Garden in Munich. He tried to persuade his assistants to join him in these early morning rides, but without great success. Six o'clock in the morning was too close to midnight. The two sports he liked best of all were fishing and hunting. These brought him closest to nature and gave him more opportunity for complete solitude. But, wherever he went, Zenneck carried his work with him so that no valuable time was ever lost.

Zenneck received many honors and decorations during his lifetime. In 1915, he became a Fellow of the Institute of Radio Engineers, and in 1917 he was made a member of the Bavarian Academy of Science. In 1923, the Bavarian government bestowed on him the title "Geheimer Regierungsrat." According to German custom, Zenneck was, thereafter, addressed as Herr Geheimrat. He jokingly referred to this title as "the official certificate for arteriosclerosis," because it was usually bestowed on meritorious gentlemen of a more advanced age. In 1926 he received the Golden Heinrich Hertz Medal, in 1928 the Medal of Honor of the IRE, and in 1933 he became vice president of the IRE. In 1946 he received the Ehrenmünze der Stadt München, and in 1956 the Siemens Ring. This is only a selection from a total of more than 30 honors and decorations Zenneck received.

In 1955, Zenneck suffered a stroke, which impaired his speech and affected his mobility. He never fully recovered. In April of 1959, he fell on the front steps of his modest home in Alshegnenberg, a suburb of Munich, where he lived after the end of the war. A few days later, on April 8, 1959, he died. Mrs. Zenneck, his faithful companion in life, died five years later. Surviving are his son, Dr. Rolf Zenneck; his daughter, Dr. Ilse Burkhardt; and seven grandchildren. His younger son, who was born after World War I, did not return from World War II. Several of Zenneck's most prominent assistants have also died: Professor Rukop, the co-author of Zenneck-Rukop's textbook of Wireless Telegraphy which had been published while Zenneck was in the United States. Dr. Rukop later became the scientific director of Telefunken. Professor Joos, whose textbook on theoretical physics received international acclaim, and who, after the war, was the director of the physics laboratory of this University. And Professor von Angerer, who was curator of the physics laboratory for many years. These three gentlemen wrote anniversary articles for Zenneck's 60th, 70th, and 80th birthday celebrations and I am sure that if they were still alive, one of them would have taken the chair today.

All those who had the good fortune of having been closely associated with Zenneck will remember him, not only as a great scientist and teacher, but also as an unpretentious man with unimpeachable character—a truly great man.